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The Status of Run II at Fermilab

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The Run II at Fermilab is progressing steadily. In the Run IIa scheme, 36 antiproton bunches collide with 36 proton bunches at CDF and D0 interaction regions in the Tevatron at 980 GeV beam energy. The current status and performance of the Fermilab Accelerator Complex is reviewed. The plans for Run IIb along with the Antiproton Source upgrade and incorporation of the Recycler Ring in the accelerator chain are outlined. The prospects of achieving Run II integrated luminosity goal of 15 fb^{-1} are discussed.

1. INTRODUCTION

The Accelerator Complex at Fermilab has delivered an integrated luminosity of 80 pb^{-} as part of collider Run IIa through August 2002. The performance has been improving steadily in the midst of many upgrades to the accelerator complex. The major components of the complex are: (1) The proton source consists of Linac and Booster; (2) The Antiproton Source containing the Debuncher and Accumulator; (3) The Tevatron as the collider storage ring for protons and antiprotons; (4) The Main Injector for accelerating and transfering beams between the beam sources and the Tevatron; (5) The Recycler Ring to be incorporated shortly in the accelerator complex as an antiproton storage facility. After a brief over view of the present collider operations in the next section, the present status of Run II is discussed in section 3. Details of the Recycler Ring commissioning and upgrades for improving the luminosity in Run IIb are outlined in sections 4 and 5.

2. OVERVIEW OF OPERATIONS

There are two important operational modes for the Fermilab accelerator complex during the collider runs [1], [2]: (1) Stacking - collecting antiprotons in the Accumulator; (2) Tevatron Shots - loading the Tevatron with protons and antiprotons for colliding stores.

During the stacking mode, the proton beam is delivered from the Booster to antiproton target via the Main Injector (MI) every 2.4 seconds. About 84 8 GeV 53MHz bunches of protons from the Booster are accelerated to 120 GeV in the Main Injector before delivery to the Antiproton target. The resulting 8 GeV antiprotons from the production target are collected, debunched and stochastically cooled in the Debuncher. Then the beam is transferred to the Accumulator where they are stacked and cooled into a ‘core’.

The Tevatron shots start with 7 53 MHz bunches of proton beam in the Booster. They are brought to the Main Injector, accelerated to 150 GeV and coalesced into one bunch and injected into the Tevatron. This is repeated until 36 bunches separated by 396 nanoseconds are loaded into the Tevatron central orbit. In the next step, antiproton beam made up of sets of 7 bunches with 53 MHz structure from the Accumulator are transferred to the Main Injector and accelerated to 150 GeV. This beam is coalesced into four bunches and injected into the Tevatron. This is continued nine times till 36 bunches of antiprotons are circulating in the Tevatron in separated helical orbits with the proton bunches. Then the whole beam is accelerated to 980 GeV and are brought into collision at the interaction regions at B0 and D0 after a low beta squeeze. A collider store normally lasts for about 1 luminosity

*Fermilab is operated by Universities Research Association, Inc. under contract with the U.S. Department of Energy lifetime that is $\sim$ 12-14 hours.

3. RUN IIa: PRESENT STATUS

The luminosity history of Run II from the beginning through August of 2002 is shown in Figure 1. Except for the periods of shutdowns, the weekly integrated luminosity is climbing steadily. The total integrated luminosity is displayed by the curve marked with diamonds reaching about $80pb^{-1}$. The important parameters characterizing the performance of the Run and the goals set for them during Run II are listed in Table 1. These numbers indicate that much progress has to be made even though considerable gains have been realized during the past several months. The major issues facing the performance have been: (1) The transverse emittance of the antiprotons from the Accumulator [3] - almost twice that during Run I for similar size of the core intensities. This reduces the transfer efficiency of the antiprotons to the Tevatron significantly; (2) The reduction of antiproton lifetime in the Tevatron via excessive emittance growth by the long range beam-beam interaction at 150 GeV.

The problem of large transverse emittance of the antiprotons from the accumulator has been solved recently by employing two lattices - one for stacking and the other for shots. Hence as of now, the beam blow-up along the transfer lines is being addressed. To reduce the long range beam-beam effects, efforts are being made to remove restrictive apertures for maximum size possible helical orbits. Other modifications for improvements such as installing more octupoles, longitudinal and transverse dampers for reduced chromaticity are in the works to be installed during the next shutdown.

4. RECYCLER COMMISSIONING

The Recycler Ring is located in the Main Injector tunnel about $\sim$ 2 meters above the Main Injector beam pipe [4]. This machine will serve as an antiproton storage ring by recycling the residual antiproton stores from the Tevatron. This Ring will improve the stacking rate of the Accumulator by rapid transfer of the antiproton stores

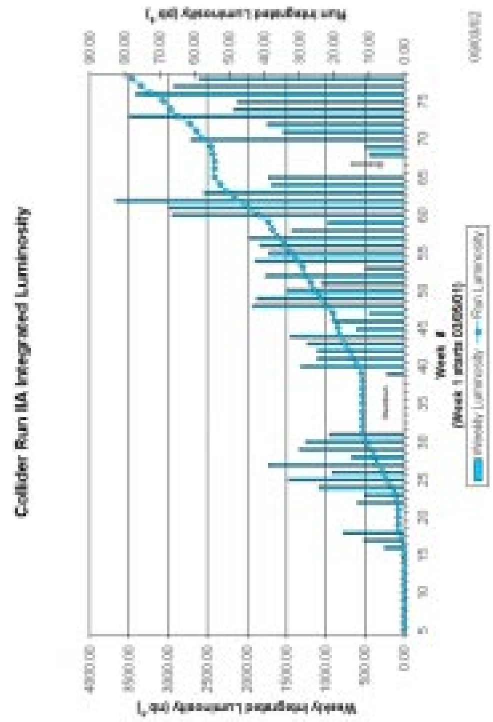

Figure 1. The Integrated Luminosity history for Run II through August, 2002.

to the Recycler. Thus the Recycler is designed to improve the overall Run II luminosity by a factor of 2-3.

The Recycler commissioning is in full swing. Both protons and antiprotons are being circulated with $>$ 85% efficiency. Presently, the antiproton lifetime with stochastic cooling is $>$100 hours even while the Main Injector is ramping. The challenging issues facing the Recycler commissioning and the proposed solutions are:

(a) To further improve the beam lifetime and curb emittance growth, the number of Ion pumps are being doubled around the ring. Combined with baking of the beam pipe longer at $> 100^0$C, the lifetime is expected to improve by a factor of 3.

(b) To improve the orbit control, new trims and

Table 1
Status on luminosity parameters as of 7/15/2002

	Highest Luminosity to 12/15/01	Highest Luminosity to date	Run IIa Goals
Maximum $\overline{p}$ stackrate (E10/hr)	10	11.4	18
Maximum $\overline{p}$ stacksize (E10)	115	144	165
$\overline{p}$ transfer Eff.	0.23	0.49	0.80
$\overline{p}$/bunch at low β (E9)	7.6	14.1	33.0
p/bunch at low β (E9)	115	211	270
Emitt. at low β (π-mm-mr)	16.0	16.3	17.5
Peak luminosity (E31 $cm^{-2}sec^{-1}$)	0.84	2.12	8.6

more diagnostics are being installed. A new and improved design of beam position monitoring devices (BPM) is being developed.

(c) Due to initial design limitations and poor matching, the beam extraction and injection apertures are small. Studies to rectify the matching problems as well as new transfer line designs are being done to improve the relevant apertures.

(d) More beam pipe sheilding is added to reduce the effect of the Main Injector ramping. Also ramping power supplies have been installed.

The present expectation is that the Recycler Ring will be commissioned and fully integrated into the Fermilab Collider Complex by the middle of 2003. Without a functioning Recycler Ring, peak luminosities in the Tevatron greater than 1E32 are probably very difficult to achieve.

5. OUTLOOK: FUTURE PLANS

As the number of protons per bunch in the Tevatron stores is limited by the beam-beam interaction, the luminosity can be improved by increasing the number of antiprotons per bunch at collisions. But the collider detectors will experience increased difficulty in reconstructing the interesting events due to multiple collisions per bunch crossing (optimum < 5). Therefore, the incrememt of the number of antiprotons per bunch should be also accompanied by increasing the number of bunches in the store. This leads to the possibility of operating the Tevatron at 132 nano second bunch separation mode with 140 proton bunches and 100 antiproton bunches.

To improve the antiproton production rate, major steps will include the following: (a) Slip stacking in the Main Injector to deliver twice the amount of protons on the production target, (b) The design of Lithium lens used to collect produced antiprotons have to be improved to increase the operating gradient from 750 $\rightarrow$ 900 T/m, (c) The transverse collection aperture in the debuncher should be improved to 30π-mm-mr from 16π-mm-mr, (d) The antiproton cooling has to be increased from 2-4 GHz $\rightarrow$ 4-8 GHz.

The 132 nsec operation of the Tevatron produces additional challenges to be overcome. The long range beam-beam effects can be $\sim$ 2 times worse while the proton beam instability could be worse by a factor 3-4! A crossing angle must be introduced at the interaction regions to avoid parasitic head-on collisions. The collider detector backgrounds could increase by a factor of 4.

REFERENCES

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